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The Impact of MMT* on Vehicle Emissions and Durability

Sharing the Automakers' Experience with China

General Motors Corporation
Ford Motor Company
DaimlerChrysler
Honda Motor Company
Volkswagen

* Methylcyclopentadienyl Manganese Tricarbonyl

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Why the Briefing ?

- **New Vehicle Emission Control Technologies designed to provide low emission performance and improved fuel efficiency are entering the global marketplace in response to consumer and government demands**
- **Clean Fuels are required to provide the designed performance of these technologies in customer driving**
- **Ash-forming additives, like MMT*, in gasoline may prevent new emission control technologies from providing their designed performance**
- **Governments around the world must understand the impact of fuel quality on vehicle emissions**
- **This briefing will provide information regarding MMT and its impact on vehicles with advanced emission controls**

* Methylcyclopentadienyl Manganese Tricarbonyl

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Emission Standards

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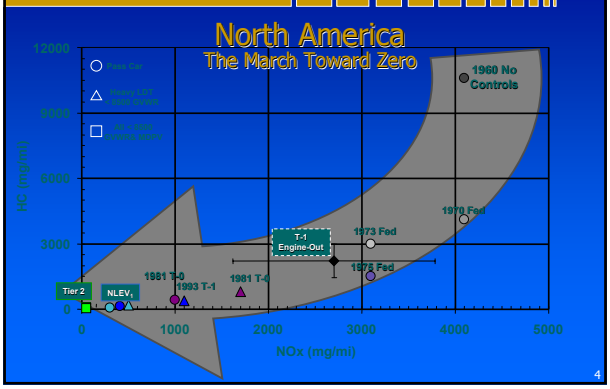
Background

Vehicle Emissions Standards



Vehicle Emissions Standards

Europe (EU)
The March Toward Zero

MMT Update/Reason for Concern

MMT Overview

- MMT - Methylcyclopentadienyl Manganese Tricarbonyl
  - Highly toxic organo-metallic compound used by refiners to improve the octane rating of gasoline (originally used as a cost effective replacement for lead which is also sold by Ethyl)
  - Impacts vehicle combustion process and damages emission control components primarily due to metal (Manganese) and metal (Mn) oxides
  - Widespread use in Canadian gasoline (since 1977)
  - Banned in Canada in 1998 but ban was lifted after legal challenges from Ethyl
  - Banned from use in reformulated gasoline (RFG) in U.S.
  - Ban was lifted in non-RFG areas of the U.S. in 1995 after years of legal battles between Ethyl and EPA
  - One US refiner began using MMT in 2002 (S-W U.S. – limited use)
  - Recently introduced in China, Australia, South America and Africa - being targeted specifically as a replacement for lead
  - OEM's are experiencing emission/component failures due to MMT, primarily in Canada and South Africa

Restrictions On The Use of MMT

- United States:
  - Banned from use in Reformulated Gasoline (RFG) used in California and other states (RFG accounts for approximately 40% of US gasoline)
  - Allowed in non-RFG @ 1/32 mg/gall (8.26 mg/litre)
- Canada
  - No limit but industry fuel specifications allows MMT use up to 18 mg/litre
  - Typically regular fuel concentration is 6 mg/litre
  - Industry suspended the use of MMT in 2004 (used in ~5% of gasoline)
- South Africa
  - Introduced in 2000 (up to 18 mg/litre)
  - Plans in place to provide MMT-free unleaded fuel by 2006?

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Reason for Concern

- MMT deposits on emission control hardware have been affecting vehicles in Canada for years
- In the past year, substantial evidence has been shared by OEM's on the impact of MMT on high-density, close-coupled catalytic converters typically used on advanced emission control vehicles
- This catalyst technology will be incorporated into most Tier 2 and EURO 3/4 certified vehicles

50,000 miles: MMT vs. MMT-free mileage accumulation

- The Auto Industry has quantified the impact of MMT on vehicle emissions and emission control components in many studies
- The latest auto study on MMT scientifically quantifies this emissions impact

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Industry Study

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MMT Studies Overview

- Previous Data
  - Many studies have been conducted in the past to determine the effects of MMT on vehicle emissions. (See Sierra Research Summary Report of MMT Studies)
  - However, over the past 25 years, the Auto Industry has consistently indicated that MMT deposits affect emission control components leading to higher emissions and poor vehicle performance.
- In 1996, the automotive industry commissioned a comprehensive study to determine the effects of MMT on vehicle emissions and durability

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Overview of Test Program

- 6 year, $8 million (U.S.) statistically designed and analyzed study conducted in two phases by independent statistician Professor Richard Gunst of Southern Methodist University
- Initial program design reviewed by the U.S. Government (EPA) and Ethyl Corporation (MMT Supplier)
- 56 vehicles from 6 major vehicle manufacturers (DaimlerChrysler, Ford, GM, Honda, Toyota, VW) equipped with latest emission control technologies available at that time
- 6.3 million kilometres of total test mileage - up to 160,000 km per vehicle
  - Controlled consumer style driving cycle, based on EPA developed cycle, for mileage accumulation on a test track
  - 4 identical vehicles of each model - "Matched Pairs"
    - 2 operating on fuel with MMT
    - 2 on same fuel without MMT

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Overview of Test Program continued

- Statistically designed/analyzed study
  - Independent statistician Professor Richard Gunst of Southern Methodist University was contracted to design the study, pick the test vehicles and analyze the data
  - Emission tests were conducted at U.S. Government (EPA and CARB) certified labs in Michigan and California
- Fuels
  - Unleaded certification quality fuel was used throughout the program for mileage accumulation of "Clear" and "Additive" fuelled vehicles
    - MMT was added at 1/32 g Manganese/gal to base fuel
  - Clear fuel meeting emissions certification testing requirements was used for all vehicle emissions testing
    - Indolene or RFG with no MMT

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Overview of Test Program continued

Tests and Analysis Conducted:

- » Federal Test Procedure (FTP) Emissions and Fuel Consumption tests at several mileage intervals
- » Highway Fuel Economy
- » Mileage Accumulation Fuel Consumption
- » Cold Temperature Carbon Monoxide
- » On-Board Diagnostics (OBD) Evaluation
- » Nitrous Oxide (N2O) on selected vehicles
- » Parts Swapping Emission Testing
- » Valve Leakage Inspection
- » Oxygen Sensor and Other Component Evaluation
- » Combustion Chamber Deposit Measurement and Removal
- » Oxygen and Air-Fuel Engine Analysis

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Study Findings

EMISSIONS

- The use of MMT in gasoline at the level of 8.26 mg Mn/Litre (1/32 g Mn per gallon);
  - Caused all four models of light-duty Low Emission Vehicles (LEV) to exceed tailpipe emission certification standards at 160,000 km
  - Significantly increased NOx emissions at 160,000 km
  - Consistently increased tailpipe NMOG* and engine-out hydrocarbon emissions for all vehicles

FUEL CONSUMPTION

- For Part 1 vehicles, fuel consumption on the road in customer-type driving increased by approximately 1% (0.1 L/100km) through 80,000 km
- For Part 2 vehicles, fuel consumption on the road in customer-type driving increased by 2% (0.2 L/100km) through 160,000 km
- A 2% increase in fleet gasoline fuel consumption represents huge increases in carbon dioxide emissions

MMT has a greater impact on vehicles equipped with advanced emission control technology

* Non-Methane Organic Gas

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Test Program Results

- **Part 1 Results**
  - **Fleet Average Emissions (g/mile)**

	Tailpipe				Engine Out			
	Clear 50K	MMT 50K	MMT Effect @ 50K	Average MMT Effect 4-50K	Clear 50K	MMT 50K	MMT Effect @ 50K	Average MMT Effect 4-50K
THC	0.088	0.103	17%	13%	1.84	2.20	20%	14%
CO	1.166	1.233	5.7%	5.7%	10.18	10.06	-1.2%	-1.0%
NOx	0.178	0.144	-19%	-10%	2.34	2.27	-3.3%	-1.1%
CO2	363	364	0.3%	0.9%	354	355	0.3%	0.8%

  - **LEV Average Emissions (g/mile)**

	Tailpipe				Engine Out			
	Clear 50 K	MMT 50K	MMT Effect @ 50K	MMT Effect @ 75K	Clear 50 K	MMT 50K	MMT Effect @ 50K	MMT Effect @ 75K
THC	0.062	0.108	72%	117%	1.37	2.24	63%	78%
CO	1.785	2.24	24%	62%	8.40	9.24	10%	20%
NOx	0.062	0.073	17%	23%	2.91	2.90	1%	5.0%
CO2	271	278	2.9%	5.4%	264	267	2.1%	3.0%

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Test Program Results continued

- **Part 2 Results**
  - **Fleet Average Emissions (g/mile)**

50K Results

	Tailpipe				Engine Out			
	Clear 50K	MMT 50K	MMT Effect @ 50K	Average MMT Effect 4-50K	Clear 50K	MMT 50K	MMT Effect @ 50K	Average MMT Effect 4-50K
THC	0.080	0.082	2.5%	2.7%	1.81	2.06	14%	11%
CO	1.109	1.098	-1.0%	-3.6%	12.07	12.33	2.2%	0.8%
NOx	0.114	0.104	-8.8%	-15%	3.16	3.06	-3.0%	-1.1%
CO2	410	419	2.2%	1.4%	387	395	2.1%	1.2%

100K Results

	Tailpipe				Engine Out			
	Clear 100K	MMT 100K	MMT Effect @ 100K	Average MMT Effect 4-100K	Clear 100K	MMT 100K	MMT Effect @ 100K	Average MMT Effect 4-100K
THC	0.090	0.118	31.1%	9.2%	1.92	2.41	25.3%	15%
CO	1.311	1.5	14.4%	-0.7%	11.62	11.93	2.7%	1.1%
NOx	0.153	0.19	24.2%	-8.4%	3.19	3.14	-1.7%	-1.1%
CO2	416	423	1.7%	1.4%	390	396	1.5%	1.2%

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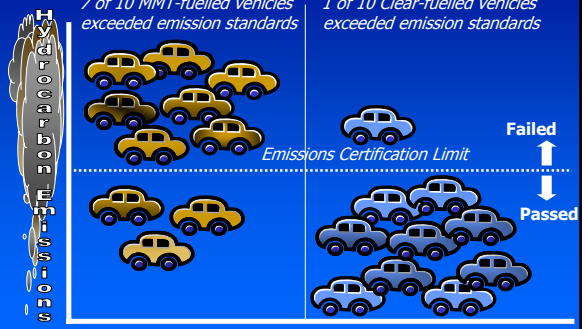
Vehicle Fleet Findings

LEV Vehicle Results (8 cars and 2 trucks)



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Test Program Observations

Typical Spark Plug Deposits

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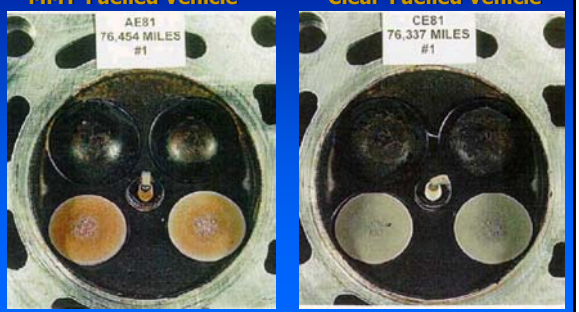
Test Program Observations continued

Typical Combustion Chamber Deposits

MMT-Fuelled Vehicle | **Clear-Fuelled Vehicle**



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Test Program Observations continued

Typical Oxygen Sensor Deposits

MMT-Fuelled Vehicle

Clear-Fuelled Vehicle

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Ford SAE Paper

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Ambient Air Emissions

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Ambient Air Emissions

Canadian Emissions Modelling (AIR study) in 2020

- Scenario 1 - Average 8.26 mg Mn/L (MMT Study level)
  - **46% Higher Smog Causing Emissions from MMT Fuelled Vehicle Fleet**
  - Projected 95,621 Tonnes of smog causing emissions avoided annually with removal of MMT
  - In addition, projected 1,062,427 Tonnes of Carbon Monoxide emissions avoided annually with removal of MMT
- Scenario 2 - Average 5.8 mg Mn/L (approx. average concentration used)
  - **32% Higher Smog Causing Emissions from MMT Fuelled Vehicle Fleet**
  - Projected 67,325 Tonnes of smog causing emissions avoided annually with removal of MMT
    - HC Emissions 34,450 Tonnes
    - NOx Emissions 32,875 Tonnes
  - In addition, projected 753,984 Tonnes of Carbon Monoxide emissions avoided annually with removal of MMT

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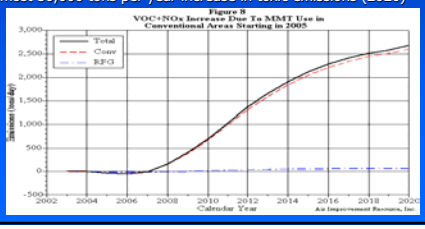
Ambient Air Emissions

United States Emission Modeling (AIR study)

- Scenario 1 - Average 8.26 mg Mn/L (MMT Study level)
  - Introduction of MMT in non-RFG fuel starting in 2005
  - Results in significant increases in smog causing and toxic emissions
    - Almost 1,000,000 tons per year increase in smog causing emissions (2020)
    - Almost 50,000 tons per year increase in toxic emissions (2020)



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Response to Ethyl Criticism of Auto Industry MMT Study

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Emission Standards / Driving Cycle

- In Part 2 of the test program, 7 of 8 LEV passenger cars exceeded emission standards when operated on fuel containing MMT (1 of 8 exceeded standards when operated on clear fuel)
- Manufacturers design and certify their vehicles to comply with emission certification standards for "full useful life"
  - All auto industry comparisons where made to certification standards
  - California allowed higher "interim" standards to encourage early introduction of LEV vehicles
  - California interim standards were not available after 1999 (also, MMT is not allowed in California gasoline)
- The driving cycle used was not aggressive
  - The original cycle was modified based on Ethyl's concerns (top speeds were reduced)
  - All vehicles were subject to the same cycle!
  - Did not subject the vehicles to "real world" driving behaviors such as high speed, towing, high loads, etc.
- The same cycle has been used by the CRC* in recent studies of engine deposits
  - Ethyl representatives are members of the CRC

*CRC (Coordinated Research Council) is a cooperative US research organization funded by the Auto and Oil industries

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Mileage Accumulation Fuels

- The objective of the study was to determine the effect of MMT on vehicle emissions
  - The only variable in the test program was the addition of MMT to the same base fuel used in all vehicles
  - If different base fuels were used, additional variables would be introduced into the scientific test
- All vehicles tested were designed to run on regular [87 (R+M)/2] octane fuel
  - No knock was reported on any of the vehicles
  - Fuel consumption on the higher octane MMT fueled vehicles were worst (should have been better as 8.26 mg/litre Mn = ~ 0.75 octane)
- There is no clear evidence that MMT lowers aromatics
  - No differences found in aromatic content in an analysis of Canadian gasoline with MMT compared to US gasoline without MMT
  - Analysis was conducted by Professor Jock Mackay, University of Waterloo - Canada

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Other Issues Raised

- Statistics
  - The MMT study was statistically designed by Professor Richard Gunst, an authority in the field of vehicle emissions whose methods are widely accepted by the auto and oil industries (industry and CRC studies)
  - Ethyl's simple statistical analysis of the data was inappropriate and lead to erroneous conclusions
  - The auto industries statistical approach was confirmed by Professor Jock MacKay of the University of Waterloo, a well respected statistical expert in Canada
- Fuel Consumption
  - As clearly pointed out in the report, on-road fuel consumption was influenced by certain vehicles, but for every vehicle pair (except for one), the MMT fueled vehicles had higher fuel consumption the the clear fueled counterpart.
- Closure
  - The 6 year, $8 million study is technically and scientifically sound
  - The experiment was designed and results were analyzed using appropriate statistical methods

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Mechanism

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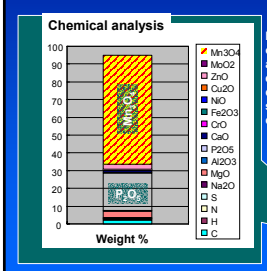
Mechanism - Deposits

MMT Additive Combustion Process

$C_5H_5MnO_3 + O_2 \rightarrow Mn_3O_4$ - melting point 1705°C + $CO_2 + H_2O$



400 CPSI Cat

Mn_3O_4 is a metal oxide - it adheres and accumulates on exhaust system components as a solid after combustion.

Valve Burning due To Exhaust leakage

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Plugging Mechanism

- Mn_3O_4 particles deposit on the front face of a catalytic converter (Similar to the diesel soot)
- At low exhaust temperature (< 700°C), they remain as powders and could be blown away
- At high exhaust temperature (> 700°C), they form a crust
- Either a low melting point material (Sulfate or Phosphate) glues the Mn_3O_4 particles together, or Mn_3O_4 particles adhere to each other through sintering
- If exists, the glue material is inorganic
- CC catalyst exhaust temps exceed 800°C regularly
  - Aggressive driving / towing, etc. temps are even higher
  - 1000°C (max) catalysts currently being developed for ultra-clean emission vehicles
- General Motors Research Paper
  - Describes catalytic converter plugging mechanism

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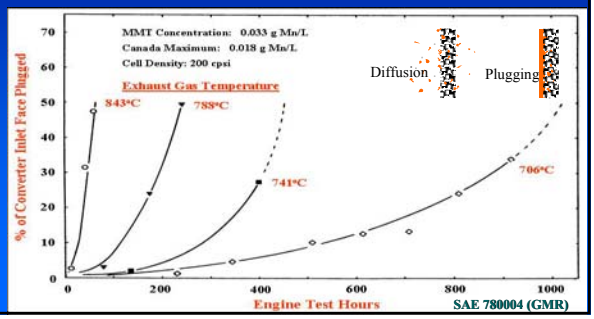
Plugging Mechanism continued

- Exhaust gas temperature is a primary contributor to time of plugging: higher exhaust temps = quicker plugging



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Plugging Mechanism continued

- There are many factors involved in the Mn catalyst plugging mechanism:
  - Catalyst temperature (exhaust gas temps)
    - Close-coupled catalysts are located and designed to operate in high exhaust gas temperature areas
    - Aggressive driving and loaded vehicles increases exhaust temperatures
  - Manganese concentration
    - Higher concentrations will result in quicker plugging
  - Area of cell opening (catalyst substrate cell density)
    - High-density catalysts will plug sooner
  - Fuel rate (amount of fuel consumed)
    - Higher fuel consumption will result in quicker plugging
    - Plugging increases with increased mileage

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Impact on Vehicles

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Impact on Vehicles - Catalysts

- Significant field issues in Canada and South Africa (many OEM's affected)
  - Due to Mn deposits plugging the face of the converter
- Significant Warranty Impact
  - Higher costs to consumers
- Significant Customer Dissatisfaction
  - Complaints of increased fuel consumption
  - Complaints of poor performance (lack of power)
  - OBD codes require service visit / catalyst replacement
- Significant Emissions Impact
  - Plugged/inefficient catalyst results in higher emissions

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Sample of Canadian Catalyst

Model year:	2001
Certification level:	LEV
Catalyst Density (Cells/in2):	400
Close coupled (Yes/No):	Yes
Analysis of Deposit (Major Component):	Mn

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Sample of Canadian Catalyst

Model year:	2002
Certification level:	LEV
Catalyst Density (Cells/in2):	600
Close coupled (Yes/No):	Yes
Analysis of Deposit (Major Component):	Mn

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Sample of Canadian Catalyst

Model year:	2002
Certification level:	Tier 2 Bin 5
Catalyst Density (Cells/in2):	600
Close coupled (Yes/No):	Semi-close
Analysis of Deposit (Major Component):	Mn (PIXE) Mn_3O_4 (XRD)
Customer complaint:	MIL on

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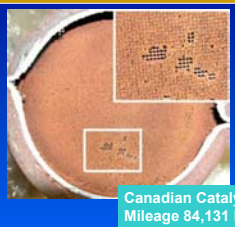
Sample of Comparable Canadian and U.S. Catalyst



Model year:	2002 / 2001
Certification level:	ULEV
Catalyst Density (Cells/in2):	600
Close coupled (Yes/No):	Yes
Analysis of Deposit (Major Component):	Mn
Customer complaint:	MIL came on & low power

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Sample of Canadian Catalyst

Canadian Catalyst
Mileage 22,623 km

Model year:	2003
Certification level:	LEV
Catalyst Density (Cells/in2):	600
Close coupled (Yes/No):	Yes
Analysis of Deposit (Major Component):	Mn

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Sample of Comparable Canadian and U.S. Catalyst

Canadian Catalyst
Mileage 97,603 km

U.S. Catalyst
Mileage 89,400 km

Model year:	2002
Certification level:	ULEV
Catalyst Density (Cells/in2):	400
Close coupled (Yes/No):	Yes
Analysis of Deposit (Major Component):	Mn, O_2

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Sample of Canadian Catalyst

Canadian Catalyst
Mileage 117,260 km

Model year:	2001
Certification level:	ULEV
Catalyst Density (Cells/in2):	400
Close coupled (Yes/No):	Yes
Analysis of Deposit (Major Component):	Mn, O_2

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Sample of Comparable Canadian and U.S. Catalyst

Canadian Catalyst
Mileage 73,066 km

U.S. Catalyst
Mileage 77,122 km

CATALYST INFORMATION		
	Canadian Vehicle	US Vehicle
Model year:	2000	2000
Odometer Reading	73,066 Km (45,402 Mi)	77,122 Km (47,923 Mi)
Certification level:	ULEV	ULEV
Catalyst cell density (cells/in^2):	600	600
Close coupled Y/N:	Yes	Yes
Analysis of deposits: % wt	60.43 Mn - O_2 31.42	N/A
Gasoline Grade:	Regular (any major brand)	Regular (Primarily BP)
Driving pattern:	50% highway 50% city	50% highway 50% city
Owner complaint:	Lack of power and MIL on	N/A

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Sample of Comparable Canadian and U.S. Catalyst

Canadian Catalyst
Mileage 29,118 kms

U.S. Catalyst
Mileage 28,416 kms

Model year:	2003MY
Certification level:	LEV
Catalyst Density (Cells/in2):	600
Close coupled (Yes/No):	Yes
Analysis of Deposit (Major Component):	Mn_3O_4
Fuel used by customer:	Regular Any Brand
Customer complaint:	Low power

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Sample of Comparable Canadian and U.S. Catalyst

Canadian Catalyst
Mileage 28,093 miles

U.S. Catalyst
Mileage 27,694 miles

Model year:	2002 MY
Certification level:	LEV
Catalyst Density (Cells/in2):	600
Close coupled (Yes/No):	Mid
Analysis of Deposit (Major Component):	Mn_3O_4
Fuel used by customer:	Misc. Brand
Customer complaint:	None – Customer in-use vehicle

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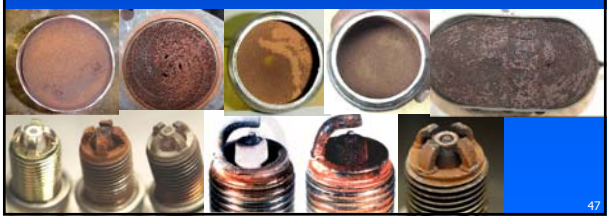
South Africa - Update

- South Africa began using MMT in October 2000 (primarily to replace leaded fuel gasoline)
  - @ 18mg/litre: One grade to be used in leaded and unleaded vehicles
- By August 2001, auto manufacturers began reporting vehicle issues (spark plug fouling, catalyst plugging, etc.)



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Conclusions

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Conclusions

- Vehicles equipped with advanced emission control technologies require clean fuel to operate as designed
- Vehicle Manufacturers unanimously support the findings of the Auto MMT study demonstrating that MMT has a detrimental impact on vehicle emissions and components
- Vehicle Manufacturers will continue to endorse the World Wide Fuel Charter recommendations for fuel properties
  - Metallic additives are prohibited from unleaded fuel
- Vehicle emissions forecast projections will NOT be met if metallic additives are used in unleaded gasoline

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Canadian Government Review Process

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Canadian Situation

- In 1998, the Canadian government issued a regulation to restrict the use of MMT – Ethyl immediately sued and after an internal review, the government rescinded the regulation and settled the suit
- Upon settlement with Ethyl in 1998, Canada committed to conduct an independent 3rd party review of any new information pertaining to MMT
- Auto industry MMT study sufficient for Environment Canada (EC) to trigger independent scientific 3rd party review of "new evidence"
  - Environment Canada (EC) released a Terms of Reference for the MMT 3rd Party Review Process in December, 2003
  - Comments on the draft document were provided in a consolidated auto industry submission (via the CVMA/AIAMC) and supported by the AAM
  - A Final Terms of Reference from EC is overdue
- The Auto Industry is fully supportive of an independent scientific review of the impact of MMT on vehicle emissions and emission components

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Independent 3rd Party Review Process

- A clear outcome from the 3rd Party Process is critical
  - Oil industry indicated that they will support the final report findings
  - EC will begin regulations to ban MMT based on the panel findings
- Review will begin shortly and is targeted to conclude by the end of 2005
  - Data submission deadline likely early spring, 2005
- Royal Society of Canada most likely to conduct the review
  - Independent Canadian Academic Organization
  - Process will likely be conducted by 7-8 "independent" experts in the area of fuels and emissions
  - Health issues and refinery emissions are not included
  - Fundamental issues will be related to the impact on hardware and associated emissions increases (i.e. proof of significant impact on air quality)
- Various Auto companies are accumulating information
  - Data will be used to support an industry submission for the 3rd Party Review

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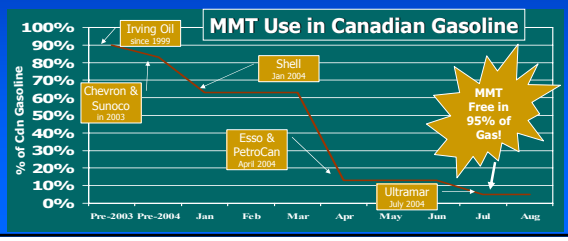
Voluntary Oil Industry Actions in Canada

- The majority of Canadian gasoline is now MMT-free
  - Auto and oil companies are working cooperatively on vehicle-fuel compatibility issues in Canada
  - Oil industry voluntarily suspended the use of MMT
  - Oil industry are supportive of the 3rd Party review process and will support final report findings



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China Test Program

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China Fuel Evaluation Test Program

- Objective or Purpose of the Program
  - How will success or failure of the program be judged?
    - What will failure be based on?
      - Failure of emissions standards?
      - Increases in emissions? By how much?
      - Statistical differences in emissions?
      - Malfunction of emission components?
  - The effects of MMT on different vehicles and emissions technology is complex and difficult to quantify
  - The Auto Industry study used 56 vehicles, took 6 years and $8 million to conduct
    - Showed significant increases in emissions on vehicles operating on fuel containing MMT
    - We encourage China to review the comprehensive study (including test methods and program design) and understand the results prior to beginning any new test program

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China Fuel Evaluation Test Program

- Experimental Design
  - Statistical principals and methodology must be used
    - Eliminate any potential sources of bias
      - 3000 km break-in on clear fuel does not represent real-world operation
      - Statistical randomization is a common approach to minimize bias
      - Random assignments of vehicle pairs should be considered
      - Mileage accumulation fuel cannot change
        - » MMT fuel must be used from the start of the program for break-in and mileage accumulation
  - Test Vehicles
    - Euro 4 emission vehicles are a good choice
      - Using one vehicle model severely limits the how the results can be used
      - MMT affects different models differently – Many factors involved:
        - » Exhaust Temperature
        - » Manganese concentration
        - » Catalyst location and density
        - » Vehicle Fuel consumption
    - Predicting the impact of fuel on the entire vehicle fleet is not possible when only one vehicle model is tested

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China Fuel Evaluation Test Program

- Test Fuels
  - How will mileage accumulation fuels be formulated?
    - Are octane levels to be maintained by adjusting aromatics and olefins?
    - Varying octane components introduces uncertainty in the test program
    - Hydrocarbon composition of fuel affects emissions, deposits, etc.
      - » Octane does not
    - Fix hydrocarbon emissions at desired level and vary only MMT
  - Emission certification fuel
    - To determine compliance with EURO emission standards, proper certification test fuel must be used when conducting emission tests
  - Other fuel properties
    - Sulfur: Stage 4 gasoline for EURO 4 vehicles limits sulfur to 50ppm
    - Detergency additives
- Vehicle Maintenance
  - Routine maintenance should not occur prior to an emission test
  - Document how non-scheduled maintenance/repairs are to be dealt

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China Fuel Evaluation Test Program

- Test Program Design
  - Repeat emission tests
    - 2 emission tests should be run (minimum) per vehicle
      - » Third test criteria should be established prior to beginning test program
  - Mileage Accumulation
    - MMT deposits increase with mileage
      - » 80,000 km may not be enough to determine long-term effects of MMT
      - » EURO 4 regulations require in-use performance for 100,000km
      - » Real-world mileage accumulation will be much higher (300,000 km+)
  - Driving Schedule
    - The driving schedule is critical and should represent most types of driving behaviors in China
      - » Speeds, acceleration rates, length of cruises, etc.
      - » Some "severe" customer behaviors should be included
  - Fuel Handling
    - Accuracy of the fuel used by each vehicle is important
      - » For calculating fuel consumption differences
      - » Avoid mis-fuelling vehicles
      - » Fuel testing for each batch of fuel to ensure specifications are met

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China Fuel Evaluation Test Program

- Reference Vehicle Tests
  - Testing emission components on an un-aged reference vehicle is questionable
    - Emission components operate as a "system"
    - MMT affects engine deposits and many emission control components
    - Testing individual components will not show the affect MMT has on a vehicle and will lead to erroneous conclusions
  - Consider exchanging components between vehicles
    - Test MMT-fueled vehicle components on clear fueled vehicles
    - Vehicle pairs would strengthen this comparison
- Other Tests
  - Particulate (PM) testing for both manganese oxide and conventional particles should be conducted
- Closure
  - If an MMT test program is to be conducted, extreme care must be taken in the design of the program to ensure proper results

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Auto Industry Recommendations

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Recommendations

- China is at a critical point relative to vehicle use
  - Transportation is growing at a very fast pace
  - Emissions from transportation must be addressed
  - Fortunately, vehicles with advanced emission control technology are widely available (Euro 4, Tier 2, LEV2, etc.)
  - Fuels must be compatible with current and future emission control technologies – MMT is not compatible with these technologies
  - Advanced vehicles and fuels can be quickly adopted by China as these technologies are widely available
- China should not allow the use of MMT in unleaded fuel
  - MMT impact on vehicles is not reversible
- China should participate in the Canadian 3rd Party Review process
  - Review to be conducted by an independent panel of scientific experts
  - Process is supported by auto and oil industry as well as Ethyl
  - Significant technical data will be presented and reviewed
- A decision to allow MMT in fuel must be thoroughly evaluated to understand the impact on vehicle emissions and air quality

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